NEW HAMPSHIRE

AGRICULTURAL

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HANOVER, N. H.,

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EXPERIMENTS WITH FERTILIZERS.

APRIL, 1889.

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— OF THE —

NEW HAMPSHIRE

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USE OF FERTILIZERS.

Farmers use fertilizers in the same way that manufacturers use their raw materials. And the same business methods and rules apply in each case. Nitrogen, Phosphoric acid and Potash, or the crude materials containing these are the farmers raw materials and from them he hopes to manufacture corn, oats, potatoes, hay fruit etc., through the agency of the soil which is his machine. The following points should be duly considered in this manufacturing process:

First. The amount of material required by various crops.

Second. The utilization of all waste products, such as animal manures, ashes etc., which are produced on the farm.

Third. The purchase of the most economical fertilizing materials as an aid to these home produced fertilizers.

Fourth. The use of all fertilizers in such a way as to get the most profitable returns, in as short a time as possible.

In all of this the final result must be determined in dollars and cents for this is the true business standard in farming as in manufacturing.

The following table shows the plant food taken from the soil by various farm crops.

"Deficient Plant Food" removed by various Crops.

		Weight as harvested. lbs.	Weight after shrinkage. lbs.	Nitrogen. lbs.	Phosphoric acid. lbs.	Potash. lbs.
Corn,	Sound, 97 bushels, Soft, 15 bushels,	4390	3512	20.55	16.27	71.07
	Fodder,	5352	4281	56.19	19.32	11.59
	Total,			76.74	35.59	82.66
Oats,	Grain, 47½ bushels,	1520	1292	24.82	7.11	5.43
	Straw,	5267	4740	18.96	8.53	45.98
	Total,			43.78	15.64	51.41
Hay,		6202	4961	60.30	21.09	95.51
Potatoes, 200 bushels,		12000		38.40	21.60	67.20
Clover, 1½ tons,			3000	64.32	16.80	58.5

Wheat,	Grain, 15 bushels,	930	19.18	7.63	5.11
	Straw, 1 ton,	2000	6.40	4.60	9.80
	Total,		25.58	12.23	14.91
Beans,	Beans, 20 bushels,	1240	50.59	14.38	14.88
	Vines,	1500	24.48	6.15	38.85
	Total,		75.07	20.53	53.73
Ensilage, 20 tons,			113.00	44 00	120.00

USE OF FARM YARD MANURE.

The general character of farm yard manure has been alluded to in Bulletin 5, page 11; it is not a concentrated fertilizer, but rather the reverse. 1562 pounds of water, 9.6 lbs of potash, 4 2-3 pounds of phosphoric acid, 9.6 pounds of nitrogen and 414 pounds of undigested matter, sand, iron, lime, magnesia etc., making up a ton. The total amount of *deficient* plant food amounting to 23.9 lbs. It will also be seen on page 12 that the amount per cord is 95.6 lbs., or if 7 cords are applied per acre the figures amount to 66.9 pounds. It must not be supposed, however, that all of this is available, for a part of the nitrogen is in the undigested food and must decompose in the soil, while a part of the phosphoric acid (about one-half of it) is insoluble. From the analyses of chemical fertilizers it will be seen that there is actualy more available plant food in a hundred pounds of corn fertilizer than there is in a ton of manure, as has been already pointed out a large part of the value of the manure of an animal is in the liquid manure in the form of *urea*, a substance containing nitrogen, and which by fermentation changes into ammonia, and is lost, or may be if no precautions are taken, this being true the safest way would seem to be to get the manure both solid and liquid into the soil before fermentation takes place. This may be accomplished by drawing and spreading the manure as fast as it accumulates whether in summer or winter. In many places this is practiced, but the deep snows of a New Hampshire winter prevent this generally, it is also true that on steep hillsides the plant food would be washed away to a certain extent, but on level land or land of moderate slope I should never hesitate to spread manure at any time when I could conveniently draw it to the field whether in the fall, winter, spring or summer. It is sometimes urged that manure loses nitrogen by exposure to wind and snow, but if manure is drawn out before fermentation commences there is little

or no ammonia in it, and as the nitrogen of manure, to be volatile must be in the form of ammonia, the loss from this source must be very small indeed; manure spread on the surface in summer or early fall should be harrowed in, for the reason that if left on the surface it dries in hard lumps and is hard to break up and mix with the soil. Manure applied in the late fall before or after the freezing of the soil, is probably in the best position possible, and I am satisfied not only from general observation and the experience of the most observing farmers, but from experiments in which the exact weight of products has been determined, that if all the farm yard manure could be applied in November instead of April that the average yield would be increased by more than ten per cent. from this change alone.

The explanation of this is to be found in the even distribution of the plant food in the surface soil. The fall rains and the melting snow soften the manure and dissolves the available plant food, washing it into the soil where it is left in the best condition possible for the young plant.

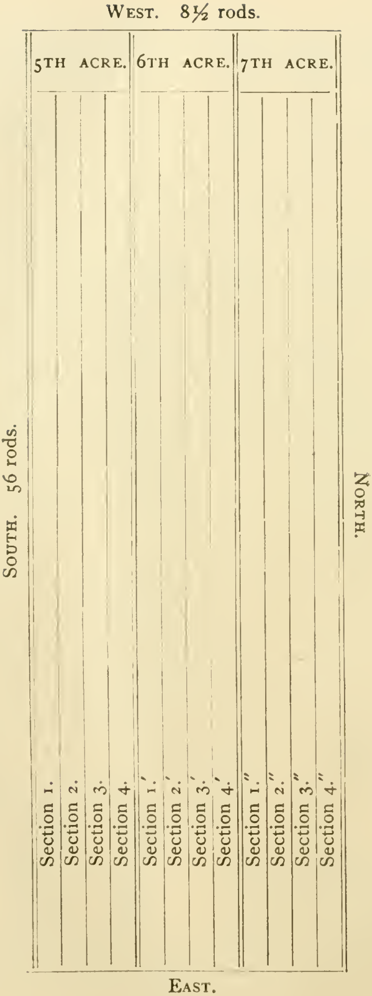
The following experiments made on the Experiment Station farm show the effects of manure applied in this way. Three acres of land were set apart for the work, the strips were fifty-six rods long and three rods wide.

Each acre was divided into four sections, and each section consisted of three rows of corn, space being left between: these spaces were planted but not included in the experiment. The three rows had eight hundred hills, the hills and rows being three feet two inches apart; this would give three-fourths of an acre in each set of four sections, which in the diagram on following page shows the field. The fifth acre had six cords of manure plowed in in the fall, the sixth acre had six cords spread on the surface in the fall, and the seventh acre had six cords spread on the surface in the spring. The yield was as follows :*

	Sound corn. lbs.	Soft corn. lbs.	Fodder. lbs.
Fifth acre plowed in in fall,	2,690	935	5,555
Sixth acre on surface in fall,	3,070	754	6,066
Seventh acre on surface in spring,	1,690	1,084	5,271

The manure was in all respects the same, so far as it is possible to get manure of like quality.

*These yields are only for three-fourths of an acre.


WEST. 8½ rods.
5TH ACRE.
6TH ACRE.
7TH ACRE.
SOUTH. 56 rods.
NORTH.
Section 1.
Section 2.
Section 3.
Section 4.
Section 1.'
Section 2.'
Section 3.'
Section 4.'
Section 1."
Section 2."
Section 3."
Section 4."
EAST.

If manure is to be stored and all applied at one time, either in the spring or fall, it should be kept under cover, the heaps well leveled down and hogs kept on it, in this way it is packed solid and the air largely excluded, this prevents fermentation to a large extent, and thus preserves the nitrogen. It is well known that sheep manure so long as it lays in the pen is packed so solid that no fermentation takes place, but as soon as thrown into a pile it quickly "heats" and gives off strong gases, this is caused by the access of air, the same is true of all manures.

A liberal use of absorbents is always to be recommended and when available there is nothing better than sawdust, no that the sawdust in itself contains much that is useful, but it readily takes up the liquids, and makes the manure easy to spread. Muck when well dried is a valuable absorbent. Straw and meadow hay are much used, but, unless of very poor quality they can be put to better use.

As a general rule manure should not be plowed in deep, more manure is lost by burying too deeply than by exposure to the air, and if it were possible to mix evenly the whole of the manure with the first three inches of surface soil, it would be in the best possible position for the ordinary crops. Every rain tends to carry the nitrogen, phosphoric acid and potash down into the soil, and the action of the air near the surface tends to render avilable the unavailable parts of the manure, but if deeply plowed in, this decomposition is slow, and often unsatisfactory.

FERTILIZERS OTHER THAN FARM YARD MANURES.

But after all the manure is used there is in most cases a deficiency to be made up, this deficiency is caused by the sale of farm products, the following table shows the nitrogen phosphoric acid and potash, carried away in one thousand pounds of the substance mentioned.

1000 lbs. of	Nitrogen.	Phosphoric acid.	Potash.
Oats,	20.0	5.33	4.25
Potatoes,	3.4	1.8	5.6
Hay,	12.8	4.25	19.3
Oat Straw,	4.0	1.8	9.7
Beans,	41.0	11.6	12.0
Corn,	16.0	5.5	3.3

	Nitrogen	Phosphoric acid.	Potash.
Milk,	5.6	1.95	2.14
Butter,	1.0	0.75	.5
Fat Oxen,	23.2	16.5	1.84
Live Hogs,	17.5	6.9	1.5
Wool,	73.0	1.0	40.0
Live Sheep,	19.6	11.39	1.6

There are two ways of making up this deficiency: by the purchase of feeding stuffs, thereby increasing the number of animals that may be kept and thus adding to the manure, and by the purchase of fertilizers, or fertilizing materials. Both methods are to be recommended, but this bulletin has for its object the consideration of the latter method, namely, the use of *fertilizing materials.*

So far as the use of *prepared* or *Commercial* fertilizers is concerned, I have only to say that my experience and that of farmers in various parts of the state has gone far towards demonstrating that more economical results may be obtained by the purchase of crude fertilizing, waste products and chemicals than by the use of the many prepared goods that are to be bought. In a considerable number of experiments it has been found that the increase of corn and fodder for a dollars worth of fertilizer applied, has been valued at about $1 50 to $2.00 with prepared goods, while mixtures of Bone-black, Muriate of Potash and Sulphate of Ammonia, have given from $2.00 to $3.00 per dollar invested. The results from the use of all fertilizers are more striking, on the hill farms and on soils of low *natural capacity* than they are on the river lands which produce larger natural crops. But as the experiments from which the foregoing averages are drawn, have been upon both kinds of soil, I think they represent the relative efficiency farely. How is this difference accounted for? I answer in two ways: 1st. because the crude chemicals contain the plant food in readily available form. Nitrogen in either Sulphate of Ammonia or Nitrate of Soda is soluble, and therefore more likely to be readily taken up by the growing crops. But in prepared fertilizers part, and often a large part of the nitrogen is in organic matter and may not be available. The potash of the easily soluble Muriate is ready for the plant at once. There seems to be some reason for believing that the phosphoric acid of bone-black is more effective than that in South Carolina Rock; at least we are sure

of our materials if bought in seperate form, while we may not be so certain about the mixed goods. But the secret of the increased efficiency of chemicals is to be looked for in the ratio in which they are mixed. It is assumed by most fertilizer manufacturers that a complete fertilizer should contain twelve per cent. of phosphoric acid, four per cent. of potash and two per cent of nitrogen, but if we look at the composition of the ash of plants we find a different ratio.

In the table given on pages 7–8 is to be found the data for determining the relative amount of potash and phosphoric acid which various crops remove from the soil. These results are represented in the following cut; the lower part of the vertical lines, or the solid black parts show the potash, the upper part, or that simply outlined represents phosphoric acid; each quarter inch in height represents 12 pounds. The table of "ratios" shows in each case the number of pounds of potash taken up by the crop for every pound of phophoric acid. For example, take the ensilage crop already described, it took from the soil forty-four pounds of phosphoric acid and one hundred and twenty pounds of potash, the ratio is 1 of P_2O_5 to 2¾ of potash K_2O with the hay crop the ratio is 1 : 4½.

Ratio of phosphoric acid to potash in the ash of plants.

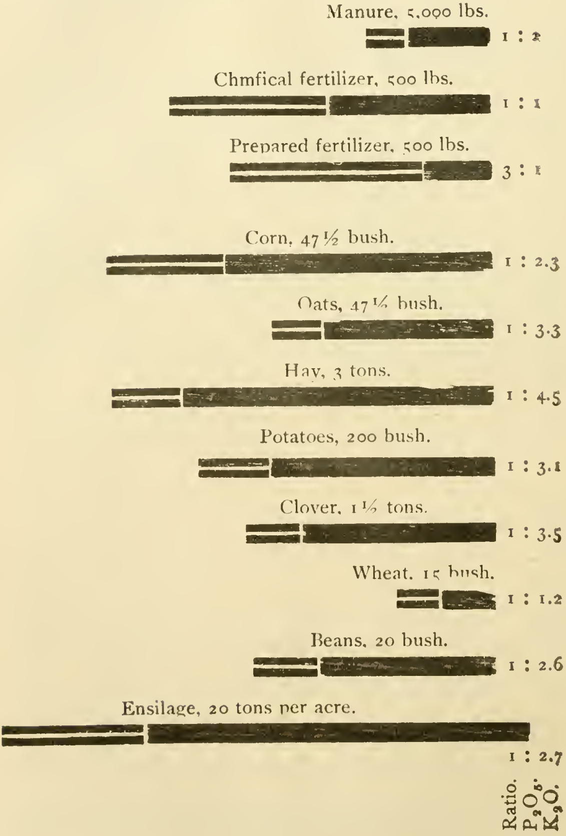
	P_2O_5.		K_2O
Ensilage,	1	:	2.7
Hay,	1	:	4.5
Corn,	1	:	2.3
Oats,	1	:	3.3
Potatoes,	1	:	3.1
Clover,	1	:	3.5
Wheat,	1	:	1.2
Beans,	1	:	2.6
In Manures.			
From Neat Cattle,	1	:	2
From Horses,	1	:	1.9
From Sheep,	1	:	2.9
From Swine,	1	:	3.1
In Prepared fertilizers,	3	:	1
Ashes,	1	:	3

It is seen at a glance that the plant requires on an average three times as much potash as phosphoric acid, while the pre-

Cut showing ration of phosphoric acid to potash.

SCALE.

One inch represents forty-eight pounds.
The black lines potash.
The light lines phosphoric acid.



pared fertilizers as we buy them, give us three times as much phosphoric acid as potash, just reversing the ratio.

Let us see what the effect of this is: suppose for example, that for a crop of corn we wish to furnish the soil with forty pounds of potash(K_2O) it will require one thousand pounds of a prepared fertilizer to give this amount; now ordinary crops would have thirteen pounds of phosphoric acid (P_2O_5) to go with forty of potash, but in our one thousand pounds of fertilizer which we must apply to get forty pounds of potash, there will be one hundred and twenty pounds of phosphoric acid, over nine times as much as is necessary, or suppose we apply enough fertilizer to provide the necessary phosphoric acid it would require but one hundred pounds, but in this amount we would only have four pounds of potash, or 1-10 of the required amount.

The average ratio of these two forms of plant food in well preserved measure is 1 of P_2O_5 to 2.5 of K_2O, and ashes which represent the ash part of trees, we find one of phosphoric acid to three of potash. Chemically then we find no support for the rule so widely adopted for compounding the so-called commercial fertilizers.

I am well aware that another factor comes in here, namely, the capacity of the soil for providing plant food.

It might be true, and doubtless is in some, perhaps many, localities that the soils yearly liberate more potash than phosphoric acid, and thêre are cases where phosphoric acid alone will give bountiful crops, thus showing that in such soils there is enough available potash, but in many cases it has been assumed that phosphoric acid is the regulating substance, when experiments carefully conducted have proven that it is potash. This leads us to inquire whether there is any method by which we may satisfy ourselves of the requirements of our particular soils.

The answer must be, field experiments! and the method must be based upon the use of fertilizing materials which contain the three forms of *deficient plant food* in seperate substances, so that we may test them singly and in a variety of combinations, having nitrogen, phosphoric acid and potash in varying proportions. These tests when well conducted and when properly duplicated and made by the side of plots having no fertilizer, are capable of giving a great deal of practical information.

PLAN OF EXPERIMENT FIELD.

PLOTS.	FOURTH ACRE.	THIRD ACRE.	SECOND ACRE.	FIRST ACRE.
15 16 17 18 19 20 21 22 23 24 25 26	No manure. 346 lbs. boneb'k. 150 lbs. muriate of potash. 56 lhs. sulphate of ammonia. Cost, $11.	13 loads manure plowed in. 9 loads harrowed in. No fertilizer in hill. Value, $33.		
12 11 10 9 8 7 6 5 4 3 2 1	352 lbs. sown bro'dcast, and 200 lbs. put in hill. 3 applications. 16 rods.		S E — W N	
15 rods.	10 rods.	10 rods.	10 rods.	10 rods.

These tests have been carried on here on the Station Farm for four years, on a series of plots, twenty-four in number. The plan of experiment has been as follows: plots of 1-20 of an acre were laid out according to the plan on page 12. This was done in 1885, each plot was seperated from the adjoining ones by a vacant space three feet wide. Each plot except those marked nothing, has received $8.00 worth of fertilizer yearly per acre for three years, 1885, 1886, 1887, or $24.00 in all. The table on page 14 shows the actual amount of each material used on each plot.

The crops were, corn, oats, and hay; with the corn the fertilizer was applied 2-3 broadcast and 1-3 in the hill, and the whole broadcast on the oats.

The table is computed to yields per acre, and as the second years crop of corn was not recorded, I have assumed that it was the same as the first, that part of the table showing value of crops is on the basis of corn, sixty cents per eighty pounds as husked, soft corn ten cents per bushel of thirty-four pounds. Fodder, $6.00 per ton, Oats fifty cents per bushel, Straw $6.00 per ton and hay $10.00 per ton. The column marked "value of crops for four years," adds the first years crop in twice, which is not far from right, this is done to facilitate comparison with the third and fourth acres given later in this bulletin. The columns showing "composition of fertilizers" gives the per cent of nitrogen, phosphoric acid and potash, in each mixture. In plot twenty-two, sulphate of potash was used the second year and the percentage is figured on the three applications, this is not strictly accurate, for the first crop had no potash at all, and the other crops were greatly benefited by the application as the yield will readily show. Had potash been added the first year, the crop would have been considerably larger.

At the bottom of the page the average of the plots with no fertilizer is given.

Plots two, three, eleven, and twelve only received fertilizers the first two years, consequently they cannot be compared with the others except for the first years corn crop.

Plot twenty-two had two application of bone, one in 1885 the other in 1887 and in 1886 an application of sulphate of potash was made.

No. of plot.	Dissolved boneblack.	Muriate of potash.	Sulphate of ammonia.	Ground bone.	Undissolved boneblack.	Krugit.	Dissolved South Carolina rock.	Undissolved S. C. rock.	Ashes.	Bay State superphosphate.	Buffalo fertilizer.	Stockbridge corn.	Bowker hill and drill.	Yield per acre. 1885. Sound corn.	Yield per acre. 1885. Soft corn	Yield per acre. 1885. Fodder.	Yield per acre. 1887. Oats.	Yield per acre. 1887. Straw.	Yield per acre. 1888 Hay.	Value of crops. 1885. Corn.	Value of crops. 1887. Oats.	Value of crops. 1888. Hay.	Value of crops. Total of three crops.	Total value of four years crop, 2nd year estimated.	Composition of fertilizer used, per ct. Nitrogen.	Composition of fertilizer used, per ct. Phosph'ic acid.	Composition of fertilizer used, per ct. Potash.	No. of plot.
									bu.					bu.	bu.	lbs.	bu.	lbs.	lbs.	$	$	$	$	$				
1		9	5											96½	39¼	7590	42½	3300	3000	55.64	31.15	15.00	101.79	157.43	7		32	1
2										20				83	27	5980	44½	2900	2650	45.54					3	12	2	2
3											20			76	27⅔	4140	44½	3000	3550	37.98					3	12	2	3
4												20		101¾	21	5290	53	3400	3050	48.49	36.70	15.25	100.44	148.93	3	12	6	4
5													20	85	18⅔	4255	45	3100	3800	40.12	31.80	19.00	90.92	131.04	3	12	2	5
*6														51¼	28	3565	41	3000	3600						0	0	0	6
7	17	¾	4		1½									80½	28½	4600	45	3600	3000	40.80	33.30	15.00	89.10	129.90	3	12	2	7
8	13	9												101½	38½	6210	53	4000	4000	52.93	38.50	20.00	111.43	164.36		9	20½	8
9	13		5											16	23	2415	40½	3300	2500	14.34	30.15	12.50	56.99	71.33	5½	16		9
10	13	4½	2½											95	35¾	6095	46	3700	3900	50.35	34.10	19.50	103.95	138.05	2½	9½	11¼	10
11											20			80¾	23⅔	3910	39	2600	3670	38.31					3	12	2	11
12										20				71½	20	3910	37	3200	3700	35.18					3	12	2	12
15									1½					105½	34	5250	40	3600	5270	50 79	30.80	26.35	107.94	158.73		2	8	15
*16														60	31	3875	34½	2600	4050						0	0	0	16
17						40								78¾	52⅓	6250	38	3900	5650	47.60	30.70	28.25	106.55	154.15			8	17
18		17												33	52	4750	38	3700	4700	29.35	30.10	23.50	82.94	112.29			50	18
*19														26	25	2250	31	3100	3550						0	0	0	19
20							32							41½	29	2625	41	3140	3000	23.22	29.92	15.00	68.14	91.36		16		20
21								36						65	30	4000	45	3140	3950	34.50	31.92	19.75	86.15	120.65		34		21
22				*20										65	27	4000	43	3100	4950	34.20	30.80	24.75	89.75	123.95	2	19	10	22
23					23									40⅓	30	3125	33	3200	3550	24.47	26.10	17.75	68.32	92.79		34		23
*24														51½	25	3375	27	3100	3200						0	0	0	24
25	27													45½	25¾	3500	36	3700	3250	26 63	29.10	16.25	72.00	98.65		15		25
26	6½	9	2½											117	32⅓	7500	40	4200	3950	60.83	32.60	19.75	113.18	174.01	2½	5¾	25	26
*Nothing.	Average of nothing plots,													47½	27¼	3246	33⅓	2900	3600	26.70	25 37	18.00	70.07	96.77	0	0	0	

This table may be studied from different standpoints, for the present I shall try to show what it teaches concerning the best combination of fertilizing materials for the crops and soil involved in this experiment.

The object of this work was to find a "ration," if I may use the term, suited to the wants of the growing plant on this soil, and so far as practicable I believe that the methods adopted in determining "rations" for animals should be applied in feeding plants; with this in view I have applied *equal values* of fertilizers in which the constituents have varied, now from the yields obtained, it is possible to pick out the best, and thus find the most profitable combination.

The feeding of plants is not essentially different from the feeding of animals, there are more factors of uncertainty in the former, but to the practical farmer it is a question of dollars received for dollars invested in each case. Hence the use of fertilizers should be studied from this point of view. The German method of adapting food to animal requirements is to feed a great variety of foods in different combinations, and note the results; after a time the superiority of certain "rations" becomes evident, and these are further tested, the foods being analized, their digestibility determined, and from the results the amount of each "digestible nutrient" consumed daily is determined. Applying this method to plants, and we should feed the plants on different plots with a "ration" made up of various fertilizing materials, the available plant food being in different proportions. Then from the yield we may pick out the most profitable combination and determine its composition, this is the true way to obtain a rational standard for fertilizers.

The great difference between adapting food to plants and to animals is this; When it has once been demonstrated that an animal under given conditions requires certain food for the best results it is reasonably certain that the results may be applied in one state or country as in another, due regard being paid to the *cost* of the food; but if I demonstrate that a certain combination in which potash is largely contained, is best for a crop of corn in a given locality it is not *certain* that on other soils having different Geological characteristics the same results would follow.

The natural resouces of the soil; its ability to provide, potash in one case, phosphoric acid in another, etc., constitute a factor of uncertainty in feeding plants which is not met with in animal nutrition, and it is this uncertainty which makes it necessary to make *local experiments* with fertilizers; I do not mean that results obtained in one place are of no value in another, for this is not the case, there are certain classes of soil which are so similar in their origin and composition that a very certain prediction may be made concerning their requirements, and it is true that the great bulk of the hill lands, or "drift soils" of New Hampshire respond similarly to fertilizers of practically the same composition; but I do mean that there are exceptions and local tests can point them out, hence the necessity for experiments on soils having unlike characteristics.

Value of crops from plot experiments.

No. of Plot.	1885. Corn.	No. of Plot.	1887. Oats.	No. of Plot.	1888. Hay	No. of Plot.	Total of three lots.	Relative position.
26	$60.83	8	$38.50	17	$28.25	26	$113.18	1
1	55.64	4	36.70	15	26.35	8	111.43	2
8	52.93	10	34.10	22	24.75	15	107.94	3
15	50.79	7	33.30	18	23.50	17	106.55	4
10	50.35	26	32.60	8	20.00	10	103.95	5
4	48 49	21	31.92	21	19.75	1	101.79	6
17	47 60	5	31.80	26	19.75	4	100.44	7
2	45.54	1	31.15	10	19.50	5	90.92	8
7	40.80	15	30.80	5	19.00	22	89.75	9
5	40.12	22	30.80	23	17.75	7	89.10	10
11	38.31	17	30.70	9	12.50	21	86.15	11
3	37.98							12
12	35.18							13
21	34.50							14
22	34.20							15
18	29.35	9	30.15	4	15.25	18	82.94	16
25	26.25	18	30.10	1	15.00	25	72.00	17
23	24.47	25	29.92	7	15.00	23	68.32	18
20	23.22	20	29.10	20	15.00	20	68.14	19
9	14.34	23	26.10	9	12.50	9	56.99	20
Plots with no fertilizers.	26.70		25.37		18.00		70 07	

The results tabulated on page 14 I have rearranged as above: commencing with the greatest value of crops, for each year and following down to the lowest, also for the total of three years, the last column shows the position as regards the best yield, the omission of oats and hay for 12th, 13th, 14th, 15th, place are occasioned by the fact that no fertili-

zer was applied to plots 2, 3, 11, and 12, after the second year.

Potash compared with Phosphoric Acid.

Plots 17 and 18 had only materials containg potash.

Plots 15 had ashes, a fertilizer containing but little aside from potash.

Plots 20, 21, 23, and 27, had phosphoric acid in various forms.

Plots 4 and 5 had prepared fertilizers.

No. 8 had no nitrogen.

No. 9 had no potash.

No. 1 had no phosphoric acid.

Nos. 10 and 26 were complete chemicals, while Nos. 6, 16, 19 and 24 had no fertilizer of any kind. The following table gives the average results from these groups. The fifth column being obtained by adding the three crops to an assumed crop for the second year equaling first year. The sixth column shows the gain in four years, due to $24.00 worth of fertilizer, each application being $8.00 per acre.

Value of crops from plots fertilized in various ways, (per acre).

	Plots.	Corn.	Oats.	Hay.	Total three years.	Total 4 years, estimating 2nd year's crop like 1st.	Value of increase crop over plots that received no fertilizer.	Value of increase of crop for $1.00 of fertilizer used.
Average from potash alone,	17, 18	$38.47	$30.40	$25.87	$94.74	$133.21	$3[illegible].44	$1.52
Nothing,	6, 16, 19, 24	26.70	25.37	18.00	70.07	96.77		
Phosphoric acid alone,	20, 21, 23, 27	27.21	29.26	17.19	73.66	100.87	4.10	0.17
Phosphoric acid and potash,	8	52.93	38.50	20.00	111.43	164.36	67.59	2.81
Phosphoric acid and Nitrogen,	9	14.34	30.15	12.50	56.99	71.33	loss.	
Phosphoric acid, potash and nitrogen,	10	50.35	34.10	19.50	103.95	154.30	57.53	2.39
Prepared or commercial fertilizers,	4, 5	44.30	34.25	17.12	95.67	139.97	43.20	1 80
Complete chemicals,	10, 26	55.59	33.35	19.62	108.56	164.15	67.38	2.80
Potash and nitrogen,	1	55.64	31.15	15.00	101.79	157.43	60.66	2.51
Ashes,	15	50.79	30.80	26.35	107.94	158.73	61.96	2.5

Phosphoric acid alone gives practically no increase of crop over unmanured plots. Potash alone gives a substantial in-

crease, holding out well as is shown by the value of the last crop. Ashes, with one exception, proves to be the most economical fertilizer, thus showing the effect of potash in another form.

Plots 1, 8, 9 and 10 constitute a series which was planned to show the effect of various combinations in which the nitrogen, phosphoric acid and potash are combined in various ways. Plot 1, gives us a total for four crops of $157.43, this plot had no phosphoric acid added, and yet the results are well up to those obtained when phosphoric acid was used. Plot 8, omitted nitrogen, but the aggregate value of the four crops stand at the head; In plot 9, potash was omitted, and it stands at the foot, being considerably below the plots that received nothing, this may be accounted for by supposing that the sulphate of ammonia used was too strong for the seeds, this preventing germination. Here we have good evidence that the omission of nitrogen in no way interferes with the yield, and if the details of crop on plot (No. 8) are looked at it will be seen that the yield holds out well in the series of crops.

Omission of phosphoric acid does not seriously cut down the yield during the first three years, but in grass there is a marked falling off. But when potash is omitted the crops fall to the lowest point. Plot 10, has a complete mixture, and if we compare it with 8, it will be seen that one half of the Muriate of Potash in 8 is exchanged for an *equal cost* of Sulphate of Ammonia in 10, the yield in 10 is good, but falls below 8 by $10.06 in four crops.

From what has been said it is evident that potash stands first, phosphoric acid second and nitrogen last. In fact we should use nitrogen but sparingly, and only when direct experimental work proves it to be profitable.

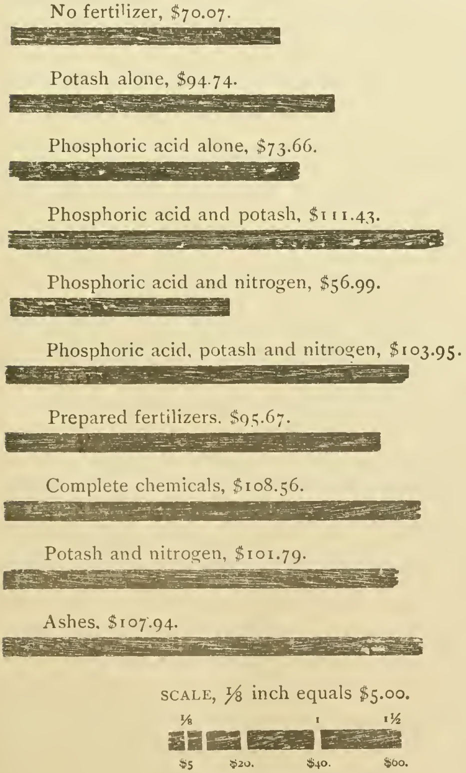
Returning to table on page 16 we will study the best six yields of each crop. Plot 8 appears in all of these; plot 15 appears in corn and hay; plot 26 appears in corn at the very head of the column. and it is fifth in oats and seventh in hay, but in the column of total values of three years crops, plot 26 leads, with No. 8 next, etc.

The following table shows the average per cent of nitrogen, phosphoric acid and potash in the fertilizers which produces the six highest yields of each crop, and of the aggregate

value of the three crops, also of the four best yields of each and of the sum of the three crops.

	Best six yields.				Best four yields.			
	Corn.	Oats.	Hay	Sum of the three.	Corn.	Oats.	Hay.	Sum of the three.
Nitrogen, per cent.,	2.5	1.8	.3	2	2.4	2.5	.5	.6
Phosphoric acid, per cent.,	6.4	13.71	10.7	4.37	4.19	10.6	5.2	4.19
Potash, per cent.,	15.5	10.80	16.1	17.46	21.4	10	19	15.4

Value of three crops (corn, oats, hay,) per acre with different manures.



The best yield of each is as follows.

	Nitrogen.	Phosphoric acid.	Potash.
Corn,	2.5	5.75	25
Oats,	0.	9.00	20.5
Hay,	0	0	8
Sum of these,	2.5	5.75	25

These results almost without exception seem to warrant the conclusion already expressed that potash and not phosphoric acid is the controling factor.

Experiments made in other parts of the state, on soils differing greatly from the Connecticut river land show even more marked results.

In the preceding cut I have represented the value of the three crops from each group of fertilizer as given in table on page 17. The lines represent dollars, one inch equaling $40, or ⅛ inch $5.00

Value of nitrogen from different sources.

The three acre experiment, the plan of which is given on page 12 was planned primarily to test manure applied in spring and fall, but each acre was divided into four sections, and these were fertilized as follows:

TABLE G.

			lbs.
5th acre.	Section 1, 800 hills,	Dissolved bone-black,	25
		Krugit.	33
		Sulphate of ammonia,	5
	Section 2, 800 hills,	Dissolved bone-black,	25
		Krugit	33
		Dried blood,	8½
	Section 3, 800 hills,	Dissolved bone-black,	25
		Krugit,	33
		Nitrate of soda,	7
	Section 4, 800 hills,	Dissolved bone-black,	25
		Krugit,	33
		Sulphate of potash,	10

6th acre.	Section 1, ′ 800 hills,	Dissolved bone-black,	25
		Krugit,	33
		Sulphate of potash,	10
	Section 2, ′ 800 hills,	Dissolved bone-black,	25
		Krugit,	33
		Nitrate of soda,	7
	Section 3, ′ 800 hills,	Dissolved bone-black,	25
		Krugit,	33
		Dried blood,	8½
	Section 4, ′ 800 hills,	Dissolved bone-black,	25
		Krugit,	33
		Sulphate of ammonia,	5
7th acre.	Section 1, ″ 800 hills,	Dissolved bone-black,	25
		Krugit,	33
		Sulphate of ammonia,	5
	Section 2, ″ 800 hills,	Dissolved bone-black,	25
		Krugit,	33
		Dried blood,	8½
	Section 3, ″ 800 hills.	Dissolved bone-black,	25
		Krugit,	33
		Nitrate of soda,	7
	Section 4, ″ 800 hills,	Dissolved bone-black,	25
		Krugit,	33
		Sulphate of potash,	10

In each case one half was sown broadcast and one half in the hill. It will be seen that each acre had one section of each kind; and so if all the sections having sulphate of ammonia, for example, were added together and compared with the sum of all that had nitrate of soda, the difference in the method of manuring the three acres would be overcome and not affect the comparative results.

TABLE H.

Yield per section of the three acres.

		Sound corn.	Soft corn.	Fodder.	Source of nitrogen.
		lbs.	lbs.	lbs.	
5th acre.	Section 1,	700	270	1,460	Sulphate of ammonia.
	" 2,	740	190	1,500	Dried blood.
	" 3,	670	240	1,390	Nitrate of soda.
	" 4,	580	235	1,205	Potash instead of nitrogen.
6th acre.	Section 1,′	735	230	1,465	Potash instead of nitrogen.
	" 2,′	745	250	1,645	Nitrate of soda.
	" 3,′	800	154	1,496	Dried blood.
	" 4,′	790	120	1,460	Sulphate of ammonia.
7th acre.	Section 1,″	480	350	1,575	Sulphate of ammonia.
	" 2,″	450	280	1,360	Dried blood.
	" 3,″	400	202	1,11[illegible]	Nitrate of soda.
	" 4,″	360	252	1,218	Potash instead of nitrogen

The following re-arrangement of these results shows the effect of the different sources of nitrogen and also of a fertilizer containing no nitrogen:

TABLE I.

Nitrogen furnished in sulphate of ammonia.

	Sound corn.	Soft corn.	Fodder.
Section 1,	700	270	1,461
" 4,′	790	120	1,460
" 1,″	480	350	1,575
Total per 2,400 hills,	1,970	740	4,496

Nitrogen furnished in dried blood.

Section 2,	740	190	1,500
" 3,′	800	154	1,496
" 2,″	450	280	1,360
Total per 2,400 hills,	1,990	624	4,356

Nitrogen furnished in nitrate of soda.

Section 3,	670	240	1,390
" 2,′	745	250	1,645
" 4,″	400	202	1,118
Total per 2,400 hills,	1,815	692	4,153

Fertilizer containing no nitrogen.

Section 4,	580	235	1,205
" 1,'	735	230	1,565
" 4,''	360	252	1,218
Total per 2,400 hills,	1,675	717	3,888

Above total results brought together:

	Sound corn.	Soft corn.	Fodder.
Sulphate of ammonia,	1,970	40	4,4957
Dried blood,	1,990	624	4,356
Nitrate or soda,	1,815	692	4,153
No nitrogen,	1,675	717	3,888

There seems to be very little choice between the three forms of nitrogen used, but it does appear in this case that nitrogen increased the crop.

Manures versus Chemicals.

One of the questions frequently asked is this: "Can chemical fertilizers compete with farm yard manures?" This question is a very important one to those who are selling hay, as well as to farmers in the vicinity of villages and cities, where farm yard manure is available. For the past four years an experiment has been carried on which has given very satisfactory results, no accident happening to either of the areas under cultivation.

Two acres of land, from a field of six acres, were selected for this experiment. The land had produced hay for three years previous to 1885, oats and sugar beets had preceded the hay.

The plan on page 12 shows the arrangement of the six acre field; the third and fourth acres are the ones to be considered.

The third acre had thirteen loads of manure plowed in and nine loads harrowed in, or in cords this would be

5.6 cords plowed in
and 3.8 cords on surface,

or 9.4 cords in all,

which would sell, as it laid under the stables, for $33.00. This manure was from fattening steers, well fed with hay, straw, cottonseed and corn meal. The fourth acre had yearly applications of chemical fertilizers, mixed as follows:

Dissolved bone black,	346 lbs.
Muriate of potash,	150 lbs.
Sulphate of ammonia,	56 lbs.

The average cost of this mixture has been $11.00, and as there has been three applications since 1885 it follows that each acre has received $33.00 worth of fertilizer; the third having $33.00 worth of manure, and the fourth $33.00 worth of chemicals.

The first year the crop was corn, the second year corn, the third oats, and the fourth grass.

The following table shows the yield of each acre for each year, and also the value of the crop, assuming eighty pounds of corn as harvested to be worth sixty cents, thirty-four pounds of soft corn ten cents, and fodder thirty cents per hundred; oats fifty cents per bushel, straw thirty cents per hundred, and hay ten dollars per ton:

	CORN.				Total yield with manure.	Total yield with chemicals.
	Third acre. Manure.		Fourth acre. Chemicals.			
	1885.	1886.	1885.	1886.		
Sound corn,*	112 bu	83¾ bu.	97 bu.	82¾ bu	195¾ bu.	179¾ bu.
Soft corn,	16½ bu.	27 bu.	15 bu.	24 bu.	43½ bu.	39 bu.
Fodder,	4835 lbs.	4435 lbs.	5352 lbs.	4927 lbs.	9270 lbs.	10279 lbs.
Value of crop,	$49.75	$41.12	$46.65	$42.00	$90.87	$88.65
	OATS, 1887.					
Grain,†	43 bu.		47½ bu.			
Straw,	4535 lbs.		5267 lbs.			
Value of crop,	$35.10		$39.55		$35.10	$39.55
	HAY, 1888.					
Yield,	5880 lbs.		6202 lbs.			
Value	$29.40		$31.01		$29.40	$31.01
Total crop for four years,					$155.37	$159.21
Excess of value for chemicals,					3.84	

*Sound corn, 40 lbs. per bushel; soft corn, 34 lbs. per bushel. †Oats, 32 lbs. per bushel.

The cost of applying the manure was $2.80. and for the three applications of chemicals $1.44.

This experiment has been carried out with the expectation of continuing it for two or three years more with grass. after which the same fertilizer should be repeated.

It will be seen from the plan of the field on page 12 that the plot experiments were immediately adjoining the fourth acre, and from the table on page 14 the following yields from plots 6,16, 19, and 24 are obtained as the *natural capacity* of the soil, no fertilizer of any kind being used on them; corn,

sound 47¼, soft, 27¼, fodder, 3246, oats, 33⅓, straw 2900 hay, 3600. From these figures it will be seen that the value of the corn crop was $26.70, the oat crop, $25.37, hay, $18.00.

The individual yield of the plots in 1886 was not determined, but I have assumed that it was the same as the previous year, though it was probably somewhat less. The total value of the four crops where no manure or fertilizers was used would

	Third acre. (Manure.)					Fourth acre. (Chemicals.)					Nothing plots.				
	Weight as harvested.	Weight after shrinkage of 20 per cent.	Nitrogen.	Phosphoric acid.	Potash.	Weight as harvested.	Weight after shrinkage of 20 per cent.	Nitrogen.	Phosphoric acid.	Potash.	Weight as harvested.	Weight after shrinkage of 20 per cent.	Nitrogen.	Phosphoric acid	Potash.
Corn. 1885 Fodder,	4835	3868	18.56	14.70	64.21	5352	4282	20.55	16.27	71.07	2796	2237	35.64	12.30	7.39
Corn. 1885 Corn,	5041	4033	64.52	22.18	13.31	4390	3512	56.19	19.32	11.59	3240	2597	12.46	9.87	43.11
Corn. 1886 Fodder,	4435	3548	17.03	13.48	58.90	4927	3942	18.92	14.98	65.42			48.10	22.17	50.50
Corn. 1886 Corn,	4268	3414	54.63	18.78	11.27	4126	3301	52.81	18.15	10.89					
Oats. 1887 Oats,	1376	1170	22.46	6.43	4.91	1520	1292	24.82	7.11	5.43	1068	961	18.4	4.8	3.68
Oats. 1887 Straw,	4535	4081	16.33	7.35	39.60	5267	4740	18.96	8.53	45.98	2900	2610	10.44	4.70	25.32
Hay, 1888,	5880	4704	60.00	19.99	90.55	6202	4962	60.30	21.09	95.51	3600	2880	35.02	12.24	55.44
Total for 4 crops,			253.53	102.91	282.75			252.55	105.45	305.87			160.06	66.08	185.44
Total in nothing plots, 4 crops.			160.06	66.08	185.44			160.06	66.[illegible]	185.44					
Difference to come from fertilizers,			93.47	36.83	97.31			92.4[illegible]	39.37	120.43					
Furnished in manure or chemicals,			362.00	175.00	361			34.00	166.00	225.00					

be $96.77, hence the gain due to manure has been $58.71, while the chemicals have given a gain valued at $62.55.

It will be interesting to see how the amount of deficient plant food in the fertilizer compares with that contained in the excess of crop, over that produced without fertilizer.

In the table showing the plant food removed by various crops I have computed the amounts removed by average crops, or perhaps by what might be termed *good* crops, in the table on page 25 is arranged the plant food, taken by each crop on acres three and four, and also on the plots having *no manure.* The difference shows the drain upon the land by the increased yield marked (*difference to come from fertilizer.*) While the last column marked (*furnished in manure or chemicals*) shows the plant food furnished in the manure, and also in the chemicals for the whole period.

It will thus be seen that in the acre fertilized with Chemicals there has been applied about four times as much phosphoric acid and nearly two times as much potash as was removed by the excess of crop over the natural production of the land, but only a little over one-third as much nitrogen was provided as the crops would seem to require. It is true that certain quantities of ammonia are yearly brought down in the rain, but this is offset by the loss in drainage water, we must conclude therefore that more of the soil nitrogen is rendered available each year than there is of the phosphoric acid or potash, and that the application of one or both of these latter substances would increase the yield without the aid of nitrogen, and as has already been shown, the potash is the element that controls, and nitrogen is comparitively useless.

There can be no doubt, that there is still potash and phosphoric acid enough left in the acre fertilized with chemicals, to give two or three more good crops of hay and it is quite probable that the supply of nitrogen will not fail.

On the acre with manure we are not so certain of our figures for the analyses of the manure is an average one taken from many sources but is probably somewhere near the truth, the phosphoric acid is about the same as that supplied in the chemicals, but the potash is considerably greater. while there has been a most wasteful amount of nitrogen applied. Allowing that there was need of supplying the whole excess of 93.47 pounds

and also that not over half of the nitrogen applied can ever be-recovered and we still have over 80 pounds more than has been used or if we consider the 34 lbs. applied on the fourth acre suf ficient, as it certainly has been, then we have 147 pounds extra, now while definite figures can be of but little use, on this point we may safely say that farm yard manure is much too rich in nitrogen in proportion to potash or phosphoric acid.

There is one point which was very clearly demonstrated in this experiment, namely the effect of fertilizer upon the *kind* of vegetation. Each acre was seeded with mixed seed, herdsgrass, redtop and alsike clover, the seed was mixed alike, sown alike and at the same time, harrowed the same, and treated in all respects in the same way, but throughout the growing season the line between the two acres was marked by the abundance of clover on the acre where chemicals were used and the absence of clover where the manure was used, this line was so well marked that when the grass was cut it was possible to divide the two acres by the line where the clover ended. In another field where nothing but chemicals have been used for five years and where a part of the field was dressed with a mixture unusually rich in potash, the same circumstance has been observed for two years, the exact line being plainly indicated by the clover on the potash side and the absence of clover on the other. The plot experiments show this more forcibly than the cases already mentioned and in the following table I have given the number of the plot, the per cent. of nitrogen phosphoric acid and potash in the fertilizer and in the next three columns the relative per cent. of herdsgrass, clovers and redtop in the hay when harvested, these proportions are of course estimated but it was done when the grass was partially dry and must be very close to the true ratio. It will be noticed that the amount of clover follows very closely the per cent. of potash in the fertilizer and as the seed sown was exactly alike on each plot there is no escape from the conclusion that potash promotes the growth of clovers.

	Composition of fertilizer.			Per ct. of each variety of grass.		
	Nitrogen.	Phosphoric acid.	Potash	Clover.	Herdsgrass.	Red top.
1	7	—	32	10	70	20
2	3	12	2	0	20	80
3	3	12	2	0	15	85
4	3	12	6	1	19	80

	Composition of fertilizer.			Per ct of each variety.		
	Nitrogen.	Phosphoric acid.	Potash.	Clover.	Herds-grass.	Red top
5	3	12	2	1	19	80
6	—	—	—	1	19	80
7	3	12	2	2	23	75
8	0	9	20.5	55	40	5
9	5.5	16	0	5	85	10
10	2.5	9.5	11.25	10	80	10
11	3	12	2	2	58	40
12	3	12	2	2	48	50
15	—	2	8	35	60	5
16	—	—	—	2	48	50
17	—	—	8	35	55	10
18	—	—	50	40	55	5
19	0	0	0	1	24	75
20	—	16	—	1	19	80
21	—	34	—	1	19	80
22	2	19	10	20	60	20
23	—	34	—	1	19	80
24	0	0	0	0	15	85
25	—	15	—	1	14	85
26	2.5	5.75	25	35	60	5

This is an important fact for it is well known that clover stores up nitrogen in the surface soil, its long deep roots gathering the costly element from the sub-soil and bringing it up within the reach of the cereals, or other crops, thus by the use of combinations containing a large per cent. of potash, we are able indirectly, through the growth of clover to increase the available nitrogen in our surface soils.

So far as results have been obtained we are justified in saying that chemicals rightly proportioned can be used as a complete substitute for farm yard manure, that they will produce as great a value of crop, dollar for dollar as manure ; and that they improve the quality of the hay by increasing the clover and, indirectly, the supply of available nitrogen is increased.

In conclusion I wish to say that I am thoroughly convinced that our fertilizer manufacturers must give us in New Hampshire more than four per cent. of potash and from other New England States, I am receiving letters which convince me that New England as a whole would be benefited by ten per cent. of potash

in the fertilizers used and were I to buy a prepared fertilizer today for our general crops I would get some one of the so called "special potato fertilizers," since they have more potash than any others on the market.

My advice to farmers is to buy dissolved bone-black, containing sixteen per cent of soluble phosphoric acid. Muriate of potash containing fifty per cent of actual potash and sulphate of ammonia containing twenty per cent. of nitrogen and from these crude materials mix such combinations as are best suited to the soil and crops under cultivation, these materials may be obtained from any fertilizer manufacturer, they are in forms that are ready for use, there is nothing to do but to mix the required amounts exactly as one would mix corn meal, shorts, and cottonseed together for feeding. It is no more labor nor is there any danger. Every farmer can experiment for himself if he buys his *deficient plant* food in these separate substances, for he is at liberty to mix them in any proportion that he pleases, and in time it would be possible for each to supply those elements which the soil most needed, and to withhold those not specially required. There certainly can be no loss, for in any event the crude chemicals will be as cheap as the manufactured goods.

The following combinations can be used to good advantage and have all been tested and found well adapted to our conditions in New Hampshire. Each combination is for one acre and in no case should more than 150 pounds be put in the hill, the remainder being sown broadcast.

I.

Chemicals for CORN and WHEAT.

Dissolved bone-black,	325
Muriate of potash,	125
Sulphate of ammonia,	75
	500

II.

CORN, (same as plot 26 in Experiments.)

Dissolved bone-black,	182
Muriate of potash,	252
Sulphate of ammonia,	66
	500

III.

Corn, (average of four best yields in plots.)

Dissolved bone-black,	175
Muriate of potash,	250
Sulphate of ammonia,	75
	500

IV.

Ensilage.

Dissolved bone black,	250
Muriate of potash,	200
Sulphate of ammonia,	50
	500

V.

Oats, (average of best four plots in Experiments.)

Dissolved bone-black,	330
Muriate of potash,	105
Sulphate of ammonia,	65
	500

VI.

Oats, (like the best plot in experiments No. 8.)

Dissolved bone black,	300
Muriate of potash,	200
	500

VII.

Hay, (average of four best crops.)

Dissolved bone-black,	225
Muriate of potash,	254
Sulphate of ammonia,	21
	500

VIII.

Hay.

Dissolved bone-black,	700
Muriate of potash,	200
Sulphate of ammonia,	50
	950

IX.

POTATOES.

Disso'ved boneblack,	340
Muriate of potash,	160
	500

X.

POTATOES.

Dissolved bone-black,	300
Muriate of potash,	150
Sulphate of ammonia,	50
	500

It will be observed that these combinations contain a considerable quantity of muriate of potash, and it must be borne in mind that if seed comes in direct contact with them there is great danger of the root being injured if not wholly destroyed. For this reason I would especially recommed that a large part of the fertilizer be used broad-cast. The amounts above given are for one acre when no manure is to be used. For corn and potatoes I would never put more than one hundred and fifty pounds in or *on* the hills or drills, and I would first plant and cover the seed as though no fertilizer was to be used, and immediately after would apply the one hundred and fifty pounds *on* the top of the hill or drill, leaving it there to be washed down into the soil by the rains, there is little if any loss in this method and I believe the results will be better than from putting the fertilizer *in* the hill.

Combination I, I would especially recommed for corn, IV for ensilage and V for oats, or as will be seen it is so much like I that the same mixture may be used for either corn or oats. However if oats follow corn that has been manured with farmyard manure, it is not necessary to use nitrogen, and in such a case I would recommend No. VI, or the potato mixture No. IX may be used.

For hay two combinations are given, the second is to be recommended if four or five crops are wanted.

For potatoes the same remarks as have been made concerning oats will apply; if the potatoes follow some crop that has been manured with stable manure, there is no need of nitro-

gen, and therefore No. IX would be best; in soils deficient in nitrogen, No. X might be best.

It will be seen from what has been said that the corn combination I, may be used for corn, wheat, oats, and on some soils for potatoes. The potato mixture IX, may be used for potatoes and oats on soils that have previously been manured, or are not deficient in nitrogen. For ensilage No. IV is to be recommended.

To mix these weigh or measure out the required amount, (See table of weights, Bulletin 5) Sweep a place on the barn floor and put down the separate substances, then shovel the mixture over until well combined, it is then ready for use, none of the substances are volatile hence there is no loss by standing.

G. H. WHITCHER, *Director.*

Bulletins sent free to all farmers in the State who send their name and address on a postal card. Farmers Organizations are requested to send in a list of names in their vicinity. We have a list of seven thousand and want to double it.

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